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Charles Thomas Johnston, Jr.

AN INVESTIGATION OF FOUR METHODS USED IN STOP-WATCH TIME STUDY FOR TIMING AND RATING WORK ACTIVITY

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SUMMARY

The primary purpose of this research was to test the hypothesis that there is no significant difference in the consistency of four methods used in stop-watch time studies for timing and rating work activity. The secondary objective was to determine the sources of variation in the consistency of the four methods.

By using one of the four methods on each of four motion pictures films of an industrial operation, a sample of 12 experienced time study men collected the original data of this study. Normal time values for each man using each method were calculated, and from these values the correct normal time values were subtracted. The remainders were used in two analysis of variance tests: one concerning normal time values for the four methods and the other concerning normal time values for three of the methods.

Method A consisted of timing and rating each cycle of the operation. Method B consisted of timing each element of each cycle and rating each cycle. Method C consisted of timing and rating each element of each cycle. Method D consisted of timing each element of each cycle and determining a rating factor for each element by considering the operator's level of performance during all repetitions of that element.

Based on the results of the statistical analysis of the data of this research and within the limitations as stated, the general conclusions reached were as follows:

1. The results of this investigation do not indicate any significant difference in the consistency of the four methods in measuring normal time for manual, operator-controlled work activity.

2. Based upon the results of this experiment, selection and use of one of the four methods of timing and rating should depend to some extent upon the individual time study man.

The final selection of a particular method should take into consideration such additional factors as ability to detect minor methods deviations when timing elements, use of elemental time values in the design of predetermined time systems, and use of element time values and cycle rating factors in the development of standard data systems.

It was recommended that another study be made on other operations to test the above conclusions. It was suggested that in any further extension of this study the time study men make the observations in the actual industrial environment of the operations in order to avoid some of the limitations of the present study.

CHAPTER I

INTRODUCTION

Fredrick W. Taylor claimed that Time Study was the basis for the major portion of Scientific Management. Since the time of the pioneers in the field of Time Study, many theories, rules, techniques, contentions, and assumptions, have been advocated by its practitioners. Some of these theories, etc., have been critically examined and found to be lacking any fundamentally sound basis. Others have been accepted and applied, sometimes even misapplied, with a blind belief in the soundness and the truthfulness of them. Such procedure on the part of the people who claim to be believers in Time Study has harmed and can continue to do harm to the scientific nature which is claimed for the field. It is only with a critical examination of the theories and techniques of Time Study that its practitioners can hope to achieve the professional status for which they so earnestly strive.

If the adjective "scientific" is to be applied to the philosophy and practice of Time Study, it would seem important to consider and examine the validity, consistency and accuracy of Time Study as it is practiced.

In order to examine and discuss Time Study practices, it is only logical that the subject be defined--if for no other reason than to insure better understanding among the discussers. Three definitions were selected to provide as representative an example as possible and also to indicate the relatively small amount of variation in the definition of Time Study from the days of its inception to the present time.

The first definition is by F. W. Taylor, as quoted by Leng. It is as follows:

> Time Study consists of two broad divisions, first, analytical work, and second, constructive work.
>
> The analytical work of time study is as follows:
>
> (a) Divide the work of a man performing any job into simple elementary movements.
>
> (b) Pick out all useless movements and discard them.
>
> (c) Study, one after another, just how each of several skilled workmen make each elementary movement, and with the aid of a stop-watch select the quickest and best method of making each elementary movement known in the trade.
>
> (d) Describe, record and index each elementary movement, with its proper time, so that it can be promptly found.
>
> (e) Study and record the percentage which must be added to the actual working time of a good workman to cover unavoidable delays, interruptions, and minor accidents, etc.
>
> (f) Study and record the percentage which must be added to cover the newness of a good workman to a job, the first few times that he does it. (This percentage is quite large on jobs made up of a large number of different elements composing a long sequence infrequently repeated. This factor grows smaller, however, as the work consists of a smaller number of different elements in a sequence that is more frequently repeated.)
>
> (g) Study and record the percentage of time that must be allowed for rest, and the intervals at which the rest must be taken, in order to offset physical fatigue.
>
> (h) Add together into various groups such combinations of elementary movements as are frequently used in the same sequence in the trade, and record and index these groups so that they can be readily found.
>
> (i) From these several records, it is comparatively easy to select the proper series of motions which should be used by a workman in making any particular article, and by summing the times of

these movements, and adding proper percentage allowances, to find the proper time for doing almost any class of work.

(k) The analysis of a piece of work into its elements almost always reveals the fact that many of the conditions surrounding and accompanying the work are defective; for instance, that improper tools are used, that the machines used in connections with it need perfecting, that the sanitary conditions are bad, etc. And knowledge so gained leads frequently to constructive work of a high order, to the standardization of tools and conditions, to the invention of superior methods and machines (1).

About 40 years after Taylor gave his understanding of the nature of Time Study, as quoted above, Barnes gives, in his popular text on the subject, his definition of Time Study as follows: "Time Study is used to determine the time required by a qualified person working at a normal pace to do a specified task (2)." Nadler in his recent text gives the following definition: "Time study determines the amount of time that should be taken on an operation or element of operation (3)."

From an examination of these three definitions it can be seen that Time Study consists mainly of measurements. Presgrave contends that Time Study is nothing but a system of measurement. He states:

Time Study fundamentally consists of two measurements, one of which is the basic measurement and the other of which is the correction factor.

There can be no other basic measurement and no other correction factor within the concept of Time Study as measurement (4).

Accepting Time Study as a system of measurement, then there are three characteristics of this "measurement" which are particularly pertinent. These characteristics are validity, consistency and accuracy. It is with continuing efforts to make Time Study more valid, more consistent, and more accurate that its practice will be based on fundamentally sound, scientific principles and laws, rather than "rule-of'thumb" techniques.

CHAPTER II

LITERATURE SURVEY

Having determined that Time Study is a system of measurements, and keeping in mind the several definitions of Time Study, we should next examine the method whereby these measurements are made, i.e., the present general practice of making stop-watch time studies.

In stop-watch time studies there are two main methods of obtaining the measurement of the actual time required to perform the particular operation. The two methods are the snap-back method and the continuous method. In the first, the stop-watch is returned to its zero position at the end of each period of time being recorded. In the latter method, the watch is allowed to run continuously throughout the total time of the study; time values being obtained by subtracting the reading at the start of a particular time element from the reading at the end of that element (5).

Prior to the actual recording of the time values, the operation under study is broken down into certain constituent parts known as elements. The breakdown of an operation into its small elements was a result of the advent of mass production with its corresponding breakdown of lengthy operations performed by skilled craftsmen into short operations performed by semi-skilled or unskilled workers (6). Littaur and Abruzzi found in their survey that the four major criterions used in determining elemental breakdown are natural and definite breaks, constant and variable elements, smallest elements consistent with accuracy and observer's judgement (7).

Once the method of timing and cycle breakdown has been determined, the next step in the practice of stop-watch time study is the determination of the number of cycles to be observed or the length of the study.

There seems to be no uniform system of determining the length of the study in general practice today. In 1933, one authority stated that the number of observations to be made was a matter which could not be definitely fixed and must be left to the judgement of the observer (8). Practically the same statement was made by two more recent writers (9,10). A survey found that the three major criterions for determining the number of cycles to be observed to attain reliable results are past experience on similar operations, length of elements or length of cycle and sufficient repetition of certain readings (11). A more recent article gives three main "schools" of thought on the subject of number of observations. The three schools are "strength in numbers" school, "selection of correct value" school and "statistical analysis" school (12).

Another major measurement which is generally made in stop-watch time study is the one of rating. The main methods of determining the rating factors are:

1. Rating the overall study.
2. Determining a rating factor for each element.
3. Rate each element and record the rating when the element is timed (13).

The last measurement to be made is the determination of allowances. This correction factor may be thought of as being composed of three separate factors. These three normally are personal allowances, fatigue allowances, and delay allowances (14). The amount of percentage of time allowed for personal needs and for unavoidable delays may be determined by all-day studies of various operations (15,16). As for the amount of allowances to permit for fatigue, some writers (17) believe that it is possible to determine it by all-day time study and the use of certain formulas, while another (18) thinks that there is no satisfactory way to measure fatigue. The general practice seems to be for companies to allow a fixed amount or percentage of the working day for fatigue. The exact amount of time thus allowed may range from 10 minutes to 30 minutes or more.

Once the time values have been recorded and the rating and allowance factors been determined, the last step in making the time study is the computation of the standard time.

The first step in the computation of the standard time is the determination of the selected time, i.e., the basic time value. There are several different methods of determining this time value, the most common of which is the arithmetic average of the recorded cycle times (19).

The next step is the application of the rating factor to determine normal time. One such method for doing this is by use of the formula (20):

$$\text{Normal Time} = \frac{(\text{Selected Time}) \times (\text{Rating in Per Cent})}{100}$$

The last step is the application of the allowance factor to determine standard time. One common method of doing this is by use of the following formula (21):

$$\text{Standard Time} = \text{Normal Time} \times \frac{100}{(100 - \text{Allowances in } \%)}$$

The resulting standard time is the time required by a qualified operator, working at normal performance, to complete the operation over a long period of time without undue fatigue. It is, by the definition of time study, the objective of all such studies.

There are other general methods of determining standard times, but they will not be discussed here in any detail as they are not within the scope of this study.

Let us now take a critical look at stop-watch time study to see what its weak points might be. This can best be done by examining separately each of the three measurements involved: rating, allowances, and basic times.

Rating.--Rating has been one of the areas of Time Study most frequently and severely criticized. One study on the leveling method of determining operator rate of performance found that this method does, in general, indicate the speed with which the work is performed, but does not take into consideration the improved detailed methods the more skilled operators are able to accomplish (22). Another author states that inconsistency in the definitions of average skill, average working conditions, fully trained operators, etc., causes errors in rating of the operator's performance (23). The ratings assigned when the stop-watch is used vary significantly from the ratings assigned when not using the stop-watch; also, the ratings are more consistent when not using the stop-watch (24).

Allowances.--One authority in the field has reported the results of extensive research at Purdue University on the subject of allowances (25).

Another author states: "Allowances do not modify previous recordings; they merely add other recordings to them (26)." Since this study will not be concerned directly with allowances, it is intended only to point out that research has been conducted in this area of time study practice.

Basic Times.--Davis claimed that there are certain errors of measurement in time study. He gave them the following classification:

1. Errors in the use of the measuring instrument.
2. Errors in selection of observed data.
3. Errors in the conversion of observed data into useful data (27).

Leng, in his study, investigated the accuracy and reliability of three different time measuring devices (28). He found that the Marsto-chron is more accurate and reliable than a wink-counter, which is more accurate and reliable than a stop-watch. He also determined the number of observations to be made for each instrument (29). Another study investigated the difference in accuracy of readings taken by continuous and snap-back methods of recording time elements and found that there was no essential difference in the two methods (30). The same results were, in general, obtained by another researcher (31).

Recent Studies.--Within recent years much work has been done on trying to eliminate and minimize some of the weaknesses of Time Study. A large amount of this work has involved the use of statistics, probability theory, and other forms of higher mathematics. One company even uses simultaneous equations to determine the standard times for reject and good pieces in short cycle inspection or test operations (32).

The techniques of Statistical Quality Control are advocated by two writers for the control of assignable variables which affect the accuracy and reliability of time study standards (33,34).

The problem of determining the number of observations, one of the weaknesses of time study methods, has been attacked by the use of statistics. Wilkinson developed a method of determining the number of observations which took into account each element reading (35). Nadler developed a method based upon determining the number required for each element, with the largest number thus determined being the number of cycle observations to be made (36). Lehrer and Moder developed a method based upon the longest element time value (37). All three of the above methods are much more easily used for a posteri determinations than for a priori determinations. The general method is to make the time study, check to see if more readings should be taken, and repeat the study using the new number of observations. These methods have certain limitations and are based on certain assumptions, either explicit or implied. Lehrer and Moder state the limitations and assumptions of their method (38).

One of the most important results of using statistics in Time Study is the elimination or minimization of variation in the final results of the study. Statistics have been used in some recent studies to determine some of the causes of variation in time studies.

One such study found that there was no evidence of a relationship between the timed variation (caused by chance variation in methods, materials, tools, etc.) and length of element; however, there was a highly significant statistical correlation between the timed variance and element complexity (39). The results of another study indicated that none of the following factors had any significant influence upon observer's inconsistencies:

1. Which operator was studied.

2. Whether the study was the first or second of a pair of studies.

3. Whether or not standard elements were used (40).

The most important causes of variation are those that arise from individual observer inconsistencies and between observers within a plant (41). Green found that the characteristics of the element time distributions and cycle time distributions are similar (42).

From a search of the literature, it appears as if a large amount of work and research has been conducted on the three separate measurements of Time Study in regard to the validity, consistency, and accuracy of these measurements. However, no reference could be found on investigation of the combination of the separate measurements of Time Study. It therefore seems worthwhile to investigate methods used in stop-watch Time Study to determine normal time, a combination of time measurement and rating factor measurement.

CHAPTER III

OBJECTIVE

This study will be concerned with a preliminary investigation of four methods of obtaining a normal time value.

The first method consists of observing and recording the performance time for each complete cycle, and determining and recording a rating factor for each complete cycle. Each cycle performance time is multiplied by the cycle rating factor, the product being the cycle normal time. Next an average of these cycle normal times is obtained. This average time is the normal time value.

The second method consists of observing and recording the performance time for each element of the cycle and determining and recording a rating factor for the entire cycle. In order to obtain a cycle performance time, the element performance times are summed. These cycle performance times are multiplied by the corresponding rating factors, thus determining cycle normal times. In order to obtain a normal time, an average is obtained of the cycle normal time values.

The third method consists of observing and recording the performance time for each element of each cycle, and determining and recording a rating factor for each element of the cycle each time the element time is recorded. Each element time is multiplied by the corresponding rating factor; thus determining an element normal time. The element normal times are added to obtain a cycle normal time. An average of these cycle normal times gives the normal time.

The fourth method consists of observing and recording the performance time for each element, and determining and recording an over-all rating factor for each element for all of the cycles studied. An average elemental time is obtained for each element. Each of these average element time values are multiplied by the corresponding rating factor; thus determining an element normal time. The sum of these element normal time values determines a normal time.

Throughout this report, the methods previously described will be known as Method A, Method B, Method C and Method D, respectively.

The consistency of each of these methods in measuring the correct normal time will be investigated by testing the following null hypotheses:

1. There is no significant difference in the mean error of the measured normal time for the four methods tested.
2. There is no significant difference in the mean error of the measured normal time due to the order in which the films were observed by the time study men.
3. The effect of the method on the mean error of the measured normal time does not vary with the order in which the films were observed by the time study men.

The above hypotheses are for manual, operator-controlled operations. The above hypotheses are to be tested at the 0.10 and 0.05 levels of significance. The error of the normal time referred to in the above hypotheses is to be composed of error in measurement of time and error in the determination of the rating factor.

In addition to the above analysis, an investigation will be made of Methods A, B, and C only. However, this investigation will be concerned with each cycle normal time instead of the overall study normal times. Since in Method D no cycle normal times are obtained, this method will be excluded from this analysis.

The consistency of Methods A, B, and C in measuring the correct cycle normal time will be investigated by testing the following null hypotheses:

1. There is no significant difference in the mean error of the measured cycle normal time due to the different methods.

2. There is no significant difference in the mean error of the measured cycle normal time for the different cycles.

3. There is no significant difference in the mean error of the measured cycle normal time due to the order in which the films were observed by the time study men.

4. There is no significant difference in the mean error of the cycle normal time due to the time study men.

5. The effect of the method on the mean error of the measured cycle normal time does not vary with the order in which the films were observed by the time study men.

6. The effect of the method on the mean error of the measured normal time does not vary with the time study man.

The above null hypotheses are for manual, operator-controlled operations. The above hypotheses will be tested at the 0.10, 0.05 and 0.01 levels of significance. The error of cycle normal time referred to in the above hypotheses is composed of error of time measurement and error of rating.

It is with hope of removing some of the doubt surrounding the source of some of the errors in stop-watch time study that this study was undertaken.

CHAPTER IV

EXPERIMENTAL PROCEDURE

The Operation.--The operation used in this experiment was a completely manual, operator-controlled operation. It was an operation which was performed in a regular industrial environment. At the time of the study, the operation was being performed according to a standard method by some 70 to 80 female, Caucasian operators in the finishing department of a mens' shirt manufacturering plant in Atlanta.

In general, the operation consists of inspecting and folding an ironed shirt prior to packaging and shipment.

Filming the Operation.--The operation was filmed on March 21, 1956, between the hours of 9:30 A.M. and 11:00 A.M. The camera used was a Cine-Kodak Special II with a Kodak Cine Ekter 15 mm f 2.5 lens. The camera was provided with a 200-foot film cartridge. The camera was modified with a syncronous constant speed motor which was connected to the main drive shaft and permitted the film to be exposed at the constant rate of 1000 frames per minute.

All shots were taken at a distance of approximately 7 feet and at an angle of approximately 60° from a lateral line which passed through the center of the operation work area. An f stop of 16 was used for taking all pictures.

A total of 1000 feet of film was exposed. Five reels of 200 feet each were taken. The first 200 feet were taken at the existing performance level of the operator, and it was later used as a familarization film. Reels number 2, 4, and 5 were also taken at the existing performance levels. Reel number 3, of 200 feet length, was taken when the operator had been instructed to slow down considerably. During the time this 200 feet of film was exposed, the operator was continually reminded, verbally, to slow her motions.

Preparing the Film.--Each of the reels of film, except for the first one taken, was examined, and all excess film was cut so that on each reel there remained 11 complete cycles. No breaks or other "mars" were present in the remaining 11 cycles, and no cycles were spliced into the films. Trailers were spliced onto each of the five films. Onto the heads of reels number 2, 3, 4, and 5 were spliced approximately one foot of clear leader, 20 frames of which contained a blue vertical mark. Next a leader was spliced onto each of the five films.

The Time Study Men.--The time study men used in the experiment were selected from companies located in the Atlanta, Georgia, area. Of the 12 men used, only one does not hold a college degree. One man has two undergraduate degrees; while two others have a Master of Science degree in Industrial Engineering.

These men's training in Time Study covered such areas as undergraduate and graduate college courses, company conducted courses, on-the-job training, and various other short courses and conferences.

The time study men were all Caucasians who ranged in age from 26 to 43, with a mean age of 33. Their experience in Time Study ranged from 6 months to 20 years.

The type of company in which they had had time study experience included such diverse fields as textile fabrication, mail-order house, aircraft manufacture, meat processing, paper fabrication, foundry, and consulting.

The Operator.--The operator used in the experiment was a qualified, adequately trained operator, who had performed the job to the extent that all learning effects had been eliminated or minimized. She was fully informed as to the nature of the experiment and the use for which the information was gathered.

Experimental Set-up.--A Bell and Howell, Time and Motion Study, Design 57, Model XD, 16mm projector was used to project the film during the experiment. By use of a voltage regulator in the line and a variable reostat on the projector, the projection speed of the film remained constant at 1000 frames per minute. The projection speed of the film was checked before and during each showing of each film with a General Radio Company, Type No. 631-B, 115 volts-60 cycles, Strobotac.

The experiment was conducted in the laboratories of The School of Industrial Engineering, Georgia Institute of Technology, Atlanta, Georgia.

The experiment was conducted in four separate groups, according to the following outline:

Group	Date	Time	Men No.
I	April 7, 1956	9:00-10:30 A.M.	1,2,3
II	April 7, 1956	10:30-12:00 A.M.	4,5,6
III	April 10, 1956	7:00- 8:30 A.M.	7,8,9
IV	April 10, 1956	7:00- 8:30 A.M.	10, 11, 12

Method A, B, C, and D was the order of use by each group of the four methods; however, the order in which the four films were shown varied from group to group. Group I saw the films in the order: Films 1, 2, 3, 4. Group II saw the films in the order: Films 2, 3, 4, 1. Group III saw the films in the order; Films 3, 4, 1, 2. Group IV saw the films in the order: Films 4, 1, 2, 3.

Each Group was first shown the familiarization film in order to allow the men the opportunity to become familar with the nature and contents of the operation. During the showing of this film, questions by the time study men of a general nature concerning the operation were answered. No indication of the operator's average earned bonus, departmental earned bonus, group incentive plan, or other similar information pertaining to the performance level of the operator was given to any of the time study men prior to the completion of the experiment.

The time study men were allowed to use either the snap-back or continuous method of timing. They were told that they might use any basis of rating they desired as long as it could be converted into 100% system. The men were instructed that they could stand or sit where they wished as long as they did not go past a certain line, which was established since the image seen at a closer distance would appear larger than life size.

After the time study men had seen the familiarization film for the first time, they were shown the same film again. The second time they saw the film they were given the element breakdown of the operation. Also the element breakpoints were pointed out to them repeatedly. The element breakdown may be seen in Figure 1 in the Appendix.

This same film was again shown to the men in order to allow them practice with the four methods used in the experiment.

Starting with the first complete cycle, they used Method 1 for one complete cycle, Method 2 for the next cycle, Method 3 for the next cycle, and Method 4 for the next four cycles. The film was then rewound and reshown to the group, and the previous procedure was repeated. Individual instruction and assistance was given as needed during the practice session. The film was reshown to allow the groups additional practice on any particular method when they so requested. Groups II, III, and IV requested additional practice on Method 3. The practice session covered about one hour of the hour and a half experiment.

Each group was given the same instructions before and during the experiment. These instructions are shown in Figure 2 in the Appendix.

CHAPTER V

ANALYSIS PROCEDURE

The data recorded on each man's observation sheet was used to compute the normal time values. Subsequent to the recording of this data by the time study men during the experiment, a film analysis was made of all four films used in the experiment. This analysis was performed by use of a Bell and Howell, Time and Motion Study, Design 57, Model XD, 16 mm projector. The same breakpoints used by the time study men during the experiment were used in the film analysis.

The time required for the performance of any foreign elements was obtained and later subtracted from the original frame count for the particular element during which the foreign element occurred. Since the time study men had been instructed to include all time in their observations, the frame count time for these foreign elements also was subtracted from the time values recorded by the time study men.

The foreign elements were as follows:

1. Toss two defective shirts aside and wait for another shirt,
2. Push stack of completed shirts aside,
3. Toss one defective shirt aside,
4. Iron back panel of shirt.

All foreign elements occurred during the first element of the cycle. These foreign elements were excluded because they do not occur during each operation, and their occurance, except for number 2, is probably randum. Foreign element number 2 had a rather fixed point of occurance.

One stack of completed shirts might consist of six shirts; the next stack consist of seven shirts; the next stack six shirts; the next six; then seven. When obtaining the films for use in the experiment, it was noted that even this supposedly ordered system for the stacking of shirts varied somewhat.

The "correct" time values for each element of each cycle for each film are shown in Tables 9, 10, 11, and 12 in the Appendix. Although these time values may not be the correct or true values, they certainly are more precise and accurate than the time values recorded by the time study men using decimal-minutes stop watches.

The "correct" normal time values for each element of each cycle were calculated next. These calculations established the "correct" rating factor values for each element of each cycle for all four methods. The "correct" rating factor values together with the "correct" film analysis frame count time values determined the "correct" normal time values, and hence the error of the normal time values as determined by the time study men. It is this error which is analyzed by this study.

The general procedure for obtaining the "correct" normal time was to multiply the mean estimate by Group I of the level of performance of the operator by the frame count time value for the particular element; add this value to the product of the mean estimate of the level of performance of the operator by Group IV and the frame count time value for the particular element; and divide the sum thus obtained by two. An illustration of this calculation procedure is shown in Figure 3 in the Appendix. This calculation was repeated for each element of each cycle. A summary of these calculations appear in Table 13.

Group IV was selected for use in establishing the "correct" rating factor values because it was the only group which used Method 3 on Film 2, and Film 2 was taken when the operator was working at a reduced level of performance as described in Chapter IV under the heading, Filming the Operation. Group I was used because it used Method 3 on Film 3, and in Film 3 the operator seems to be more consistent in her level of performance.

Again, the "correct" rating factors used in this study are not the correct or true ones. If the true rating factors were known, then many of the problems of Time Study would be solved. It is believed, however, that the procedure used for establishing "correct" rating factor values was a satisfactory one for this particular study. In the future, the quotation marks around the work correct will be omitted.

The next step in analyzing the data was to determine a correct rating factor value for each element of each cycle for each film. A sample of this calculation is shown in Figure 4. A summary of these calculations is shown in Table 14 in the Appendix.

The next step in the analysis procedure was to obtain a correct "over-all" rating factor value for each element for each film. The method for obtaining these values is shown in Figure 5 in the Appendix. The correct "over-all" rating factor value for all elements are shown in Table 15.

The correct rating factor value for each cycle of each film was determined next. The method for performing this calculation is shown in Figure 6 in the Appendix. The correct rating factor value for each cycle of each film is shown in Table 16.

The next step was to calculate the correct normal time value for each group for each method. These coreect normal time values are composed of the frame count time values and the correct rating factor values as previously determined. Illustrations of these calculations are shown in Figures 7, 8, 9, and 10 in the Appendix. A summary of these values is shown in Table 1.

Next, the measured normal time values for each time study man for each method was calculated. Illustrations of these calculations are shown in Figures 11, 12, 13, and 14 in the Appendix.

The statistic used in the analysis of the four methods is the difference between the correct normal time value and the measured normal time value.

The analysis procedure used to analyze the three methods, which resulted in normal cycle time values for each cycle, was the same as the one used for the analysis of the four methods, with the exception of performing the calculations of correct normal time values and measured normal time values. As part of these two calculations, it was necessary to calculate the correct cycle normal time values for each cycle of each film and also the measured normal time values for each cycle of each film for each man. As a result, these calculations are not shown separately.

The statistic used in the analysis of the three methods is the difference between the correct cycle normal time value and the measured cycle normal time value.

CHAPTER VI

ANALYSIS OF RESULTS

Four-method Analysis.--The general statistical technique or test used was the one of analysis of variance.

An analysis of variance table was constructed and a model equation was written. The next step was to determine the expected value of the mean squares for each source of variation. In making this determination, the system advocated by Schultz (43) was used. Each of these determinations are shown in Figure 15 in the Appendix.

The statistic used in the analysis was the difference between the correct normal time value and the measured normal time values as determined by the time study men. The correct normal time values for each method for each group is given in Table 1.

Table 1. Correct Normal Time Values, in Minutes, for Each Group Using Each Method

Method Number of	Group I	II	III	IV
A	0.69570	0.65050	0.70704	0.69739
B	0.69611	0.70704	0.69636	0.69693
C	0.67167	0.67167	0.67167	0.67167
D	0.68776	0.69687	0.69207	0.69628

The measured normal time values for the time study men are given in Table 2. The difference in these values for each man for each method was obtained, rounded to four decimal places; and the decimal point moved four places to the right as an aid in computations. The results are shown in Table 3.

The next step was the determination of the sum of squares for each source of variation. Using the data in Table 3, each component of the sum of squares for the various sources was computed. From these figures the numerical value for the sum of squares for each source was obtained. The mean squares were computed for each source, and the F ratio was then obtained. Using a Table of F values (44) the calculated F ratios were tested at the 0.10, 0.05 and 0.01 levels of significance. The results are shown in Table 4.

As a result of the analysis of variance, the null hypothesis that there is no significant difference in the mean error of the measured normal time for the four methods tested can not be rejected. The large amount of variation due to the individual time study men, as indicated by the sum of squares for this source, of variation, as compared to the amount of variation due to the methods, as indicated by the sum of squares for this source, may give some indication of why the variation in mean error within the four methods was not more significant.

The null hypothesis that there is no significant difference in the mean error of the measured normal time due to the order in which the films were observed by the time study men can not be rejected on the results of the analysis of variance test. This result is highly desirable since the purpose of rotating the order of presentation of the films

Table 2. Measured Normal Time Values, in Minutes, for Each Man Using Each Method

Man Number of	Method A	B	C	D
1	0.54460	0.45375	0.53015	0.51145
2	0.70320	0.70270	0.76900	0.71468
3	0.62580	0.60049	0.57111	0.54555
4	0.53910	0.56609	0.56915	0.65458
5	0.56200	0.61747	0.60125	0.61022
6	0.46573	0.52309	0.54018	0.60260
7	0.63760	0.63746	0.62179	0.57807
8	0.55770	0.57162	0.58955	0.53837
9	0.62063	0.69022	0.69751	0.66625
10	0.51212	0.56103	0.51103	0.54508
11	0.66790	0.69827	0.62694	0.59692
12	0.62924	0.68085	0.56521	0.57488

Table 3. Mean Error in the Measured Normal Time Values

Order Number Of	Man Number Of	Method			
		A	B	C	D
	1	1511	2424	1415	1763
1	2	75*	66*	973*	269*
	3	699	956	1006	1422
	4	1114	1410	1025	423
2	5	885	896	704	867
	6	1848	1040	1315	943
	7	694	594	499	1140
3	8	1493	1252	821	1537
	9	864	66	258*	258
	10	1853	1358	1606	1512
4	11	295	14*	447	994
	12	682	160	1065	1214

* - Indicates an error greater than the correct value.

All figures are in ten-thousandths of a minute.

Table 4. Results of Analysis of Variance for Four Methods

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
M	3	586,382	195,461	2.20
O	3	594,424	198,141	0.11
t	8	14,652,576	1,831,572	
MO interaction	9	2,314,554	257,173	2.90*
Mt interaction	24	2,131,407	88,809	

M and MO tested against Mt

O tested against t

*- Significant at 5% level of significance.

was to be able to measure and eliminate this source of variation in the testing of the hypotheses of interest.

The null hypothesis that the effect of the method on the mean error of the measured normal time does not vary with the order of presentation of the films is rejected at the 5% level of significance. This means that the relative consistency of the methods in determining the correct normal time depended upon the order in which the films were observed by the time study men. Each man did not use each method on each film; therefore, the dependence of the consistency of the method upon the order of films seem a natural result of experiment design, which, although undesirable, was unavoidable.

Three-method Analysis.--The same general procedure was used in this analysis as was used in the Four-method analysis.

An analysis of variance table was constructed and the model equation was written. The next step was to determine the expected values of the mean squares for each source of variation. Again, the system advocated by Schultz was used. These determinations appear in Figure 16.

The statistic used in this analysis was the difference between the correct cycle normal time value and the measured cycle normal time value. The correct cycle normal time values are given in Table 5. The measured cycle normal time values for each man are shown in Table 6. The differences in these figures were obtained; the figure rounded to four decimal places; and the decimal place moved four places to the right. The results are given in Table 7.

Using the data in Table 7, the sum of squares was computed for each source of variation. From the sum of squares the mean squares were

Table 5. Correct Cycle Normal Time Values, in Minutes

Order Number Of	Cycle Number Of	Method A	Method B	Method C
	1	0.62145	0.62338	0.62142
	2	0.67448	0.66503	0.53690
	3	0.71920	0.71918	0.71917
	4	0.67414	0.67414	0.67416
	5	0.67536	0.67538	0.53772
1	6	0.72834	0.72884	0.72837
	7	0.79933	0.79970	0.79971
	8	0.66631	0.67727	0.67725
	9	0.69474	0.69448	0.69477
	10	0.69824	0.69820	0.69823
	11	0.70139	0.70165	0.70067
	1	0.62142	0.62142	0.62142
	2	0.66533	0.74182	0.53690
	3	0.71916	0.71914	0.71917
	4	0.67414	0.71492	0.69416
	5	0.67537	0.67542	0.53772
2	6	0.72837	0.72630	0.72837
	7	0.79970	0.80661	0.79971
	8	0.67727	0.67723	0.67725
	9	0.69477	0.69477	0.69477
	10	0.69820	0.69822	0.69823
	11	0.70165	0.70164	0.70067
	1	0.62142	0.62143	0.62142
	2	0.74182	0.67482	0.53690
	3	0.71914	0.71916	0.71917
	4	0.71492	0.67416	0.67416
	5	0.67542	0.67540	0.53772
3	6	0.72630	0.72839	0.72837
	7	0.80661	0.79970	0.79971
	8	0.67723	0.67773	0.67725
	9	0.69477	0.69678	0.69477
	10	0.69822	0.69825	0.69823
	11	0.70164	0.70168	0.70067

Table 5. Correct Cycle Normal Time Values, in Minutes

(Continued)

Order Number Of	Cycle Number Of	Method A	Method B	Method C
	1	0.62143	0.62145	0.62142
	2	0.67482	0.67483	0.53690
	3	0.71916	0.71920	0.71917
	4	0.67416	0.67441	0.67416
	5	0.67540	0.67536	0.53772
4	6	0.72839	0.72834	0.72837
	7	0.79969	0.79973	0.79971
	8	0.67725	0.67722	0.67725
	9	0.69478	0.69474	0.69477
	10	0.69825	0.69824	0.69823
	11	0.70801	0.70164	0.70067

Table 6. Measured Cycle Normal Time Values, in Minutes

Man Number Of	Cycle Number Of	Method A	B	C
	1	0.53100	0.48070	0.43320
	2	0.52250	0.41800	0.47900
	3	0.47120	0.48400	0.53580
	4	0.56320	0.43000	0.51190
	5	0.52720	0.39600	0.50400
1	6	0.54900	0.41650	0.56415
	7	0.54900	0.46240	0.56530
	8	0.56700	0.47000	0.53120
	9	0.48000	0.52470	0.60870
	10	0.62600	0.45000	0.53260
	11	0.60500	0.45900	0.56480
	1	0.79650	0.72000	0.65000
	2	0.74100	0.64800	0.74650
	3	0.73080	0.74200	0.83730
	4	0.73600	0.61200	0.79250
	5	0.83625	0.67500	0.74490
2	6	0.78750	0.74100	0.82925
	7	0.80000	0.77220	0.87800
	8	0.78000	0.72900	0.80075
	9	0.82680	0.67850	0.70030
	10	0.70000	0.68400	0.67950
	11	0.78750	0.72800	0.80000
	1	0.63000	0.50920	0.54400
	2	0.55100	0.55200	0.51000
	3	0.53010	0.44800	0.59260
	4	0.61750	0.58300	0.61350
	5	0.63555	0.47500	0.57060
3	6	0.63000	0.43200	0.59820
	7	0.66150	0.61320	0.54120
	8	0.67200	0.62100	0.59700
	9	0.68200	0.62700	0.58710
	10	0.63600	0.57750	0.55900
	11	0.63800	0.59000	0.56900

Table 6. Measured Cycle Normal Time Values, in Minutes

(Continued)

Man Number Of	Cycle Number Of	Method A	Method B	Method C
	1	0.50940	0.54600	0.55000
	2	0.53000	0.57750	0.59800
	3	0.52000	0.58500	0.50550
	4	0.50000	0.55100	0.60500
	5	0.52800	0.51650	0.60025
4	6	0.51300	0.59130	0.59650
	7	0.52560	0.60300	0.56800
	8	0.53000	0.64175	0.59790
	9	0.59850	0.50800	0.54750
	10	0.59850	0.57600	0.52400
	11	0.57750	0.53100	0.56800
	1	0.51870	0.55000	0.54800
	2	0.56000	0.56700	0.56100
	3	0.50350	0.64000	0.58500
	4	0.47500	0.58000	0.65950
	5	0.53000	0.65400	0.65150
5	6	0.56700	0.67935	0.62850
	7	0.62370	0.66000	0.59050
	8	0.57750	0.64350	0.60670
	9	0.63000	0.57540	0.58500
	10	0.58800	0.60500	0.58300
	11	0.60900	0.63800	0.61500
	1	0.51870	0.60000	0.47050
	2	0.52250	0.49500	0.51550
	3	0.50350	0.57600	0.57300
	4	0.51000	0.47200	0.56200
	5	0.50000	0.48060	0.61300
6	6	0.51300	0.53360	0.56100
	7	0.46720	0.48000	0.56350
	8	0.45600	0.49200	0.59000
	9	0.48450	0.60280	0.43900
	10	0.55100	0.55000	0.51100
	11	0.54150	0.47200	0.53900

Table 6. Measured Cycle Normal Time Values, in Minutes

(Continued)

Man Number Of	Cycle Number Of	Method A	Method B	Method C
	1	0.57600	0.62500	0.52000
	2	0.60950	0.62500	0.64300
	3	0.69000	0.62400	0.59205
	4	0.63250	0.69000	0.64000
	5	0.59110	0.66125	0.67105
7	6	0.68655	0.60500	0.64500
	7	0.70800	0.60950	0.65000
	8	0.64975	0.63480	0.63200
	9	0.58420	0.67500	0.62055
	10	0.59800	0.63750	0.61650
	11	0.68750	0.62500	0.60950
	1	0.51450	0.52500	0.57950
	2	0.53550	0.55000	0.55950
	3	0.60000	0.58300	0.59510
	4	0.53000	0.60900	0.61000
	5	0.50730	0.62475	0.64350
8	6	0.61700	0.59850	0.61350
	7	0.58235	0.49500	0.57750
	8	0.54500	0.62160	0.59200
	9	0.54390	0.57200	0.57100
	10	0.56100	0.50400	0.55740
	11	0.59850	0.60500	0.58600
	1	0.62400	0.62500	0.71420
	2	0.65000	0.65000	0.63500
	3	0.61000	0.66250	0.72595
	4	0.53900	0.70800	0.72350
	5	0.57400	0.71875	0.68590
9	6	0.62685	0.70000	0.64350
	7	0.64050	0.66300	0.61100
	8	0.56175	0.75870	0.69800
	9	0.56980	0.68900	0.73000
	10	0.70200	0.70200	0.83460
	11	0.72900	0.71550	0.67100

Table 6. Measured Cycle Normal Time Values, in Minutes

(Continued)

Man Number Of	Cycle Number Of	Method A	B	C
	1	0.51000	0.56000	0.48126
	2	0.59000	0.51300	0.61150
	3	0.52000	0.55900	0.47700
	4	0.52200	0.62000	0.48050
	5	0.50850	0.55710	0.47060
10	6	0.54000	0.57000	0.49250
	7	0.51450	0.56050	0.51060
	8	0.49680	0.56050	0.50400
	9	0.51000	0.57680	0.52620
	10	0.53550	0.55440	0.54160
	11	0.48600	0.54000	0.52560
	1	0.60000	0.68400	0.60500
	2	0.62500	0.73200	0.64550
	3	0.65000	0.56235	0.55050
	4	0.79300	0.71400	0.61000
	5	0.66600	0.68145	0.54000
11	6	0.67200	0.68200	0.65150
	7	0.62400	0.72450	0.68830
	8	0.73060	0.76800	0.54300
	9	0.68900	0.70200	0.70200
	10	0.63750	0.77520	0.68550
	11	0.66000	0.65550	0.67500
	1	0.63750	0.68900	0.50420
	2	0.62500	0.70200	0.63350
	3	0.63600	0.54470	0.51600
	4	0.65550	0.67850	0.53150
	5	0.63825	0.74280	0.47800
12	6	0.66000	0.72000	0.59250
	7	0.66000	0.73750	0.55560
	8	0.53390	0.74400	0.56550
	9	0.62500	0.74100	0.59900
	10	0.62500	0.52740	0.59650
	11	0.64800	0.66250	0.64500

Table 7. Mean Error in Measured Cycle Normal Time Values, in Ten-Thousandths of a Minute

Order Number Of	Man Number Of	Cycle Number Of	Method A	B	C
		1	905	1427	1882
		2	1520	2470	579
		3	2480	2352	1834
		4	1109	2441	1623
		5	1482	2794	337
	1	6	1793	3123	1457
		7	2503	3373	2344
		8	993	2073	1461
		9	2147	1698	861
		10	722	2482	1656
		11	964	2427	1359
		1	1751*	966*	286*
		2	665*	170	2096*
		3	116*	228*	1181*
		4	619*	621	1183*
		5	1609*	4	2072*
1	2	6	592*	122*	1009*
		7	7*	275	783
		8	1137*	517*	1235*
		9	1321*	160	55*
		10	18*	142	187
		11	861*	264*	993*
		1	86*	1142	774
		2	1235	1130	269
		3	1891	2712	1266
		4	564	911	607
		5	396	1994	329*
	3	6	983	2968	1302
		7	1378	1865	2585
		8	57*	563	803
		9	127	675	1077
		10	622	1207	1392
		11	634	1117	1317

Table 7. Mean Error in Measured Cycle Normal Time Values, in Ten-Thousandths of a Minute

(Continued)

Order Number Of	Man Number Of	Cycle Number Of	Method A	Method B	Method C
		1	1120	754	714
		2	1350	1643	611*
		3	1992	1341	2137
		4	1741	1639	692
		5	1474	1589	625*
	4	6	2154	1350	1319
		7	2741	2036	2317
		8	1473	355	794
		9	963	1868	1473
		10	997	1222	1742
		11	1242	1706	1327
		1	1027	714	734
		2	1050	1748	241*
		3	2157	791	1342
		4	1991	1349	147
		5	1454	214	1138*
2	5	6	1614	470	999
		7	1760	1466	2092
		8	998	337	706
		9	648	1194	1098
		10	1102	932	1162
		11	927	636	857
		1	1027	214	1509
		2	1463	2468	214
		3	2157	1431	1462
		4	1641	2429	1122
		5	1754	1948	753*
	6	6	2154	1927	1674
		7	3325	3266	2362
		8	2213	1852	873
		9	2103	920	2588
		10	1472	1482	1872
		11	1602	2296	1617

Table 7. Mean Error in Measured Cycle Normal Time Values, in Ten-Thousandths of a Minute

(Continued)

Order Number Of	Man Number Of	Cycle Number Of	Method A	B	C
		1	454	36*	1014
		2	1323	498	1061*
		3	291	952	1271
		4	824	158	342
		5	843	142	1333*
	7	6	397	1234	834
		7	986	1902	1497
		8	275	429	453
		9	1106	198	742
		10	968	608	817
		11	142	767	912
		1	1069	964	419
		2	2063	1248	225*
		3	1191	1362	1241
		4	1849	652	642
		5	1681	507	1058*
3	8	6	1093	1299	1149
		7	2243	3047	2222
		8	1322	561	618
		9	1509	1228	1238
		10	1372	1943	1408
		11	1031	967	1147
		1	26*	36*	928*
		2	918	248	981*
		3	1091	567	678*
		4	1759	338*	493*
		5	1014	434*	1482*
	9	6	995	284	849
		7	1661	1367	1287
		8	1155	810	208*
		9	1250	58	352*
		10	38*	38*	1364*
		11	274*	138*	297

Table 7. Mean Error in Measured Cycle Normal Time Values, in Ten-Thousandths of a Minute

(Continued)

Order Number Of	Man Number Of	Cycle Number Of	Method A	Method B	Method C
		1	1114	615	1402
		2	1848	1618	746*
		3	1992	1602	2422
		4	1522	644	1937
		5	1669	1183	671
	10	6	1884	1583	2339
		7	2852	2392	2891
		8	1805	1166	1733
		9	1848	1179	1686
		10	1628	1438	1566
		11	2220	1616	1751
		1	214	626*	164
		2	498	572*	1086*
		3	693	1568	1687
		4	1188*	360*	642
		5	94	61*	23*
4	11	6	564	463	769
		7	1759	752	1114
		8	534*	908*	1343
		9	58	73*	72*
		10	608	770*	127
		11	480	461	257
		1	161*	676*	1172
		2	498	272*	966*
		3	832	1745	2032
		4	186	41*	1427
		5	372	674*	597
	12	6	684	83	1728
		7	1622	622	2441
		8	1434	668*	1118
		9	698	463*	958
		10	733	1708	1017
		11	600	391	557

*- Indicates an error greater than the correct value.

Table 8. Results of Analysis of Variance for Three Methods

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
c	120	136,289,835	1,135,749	6.38*
M	2	6,455,600	3,227,800	3.22**
O	3	26,105,826	8,701,942	0.48
t	8	144,586,844	18,073,356	10.16*
MO interaction	6	27,167,649	4,527,942	3.99*
Mt interaction	16	16,050,486	1,003,155	5.64*
ct interaction	240	42,709,493	177,956	

c,t, and Mt tested against ct

M tested against Mt

O tested against t

MO tested against c

* Significant at 10% level of significance
** Significant at 1% level of significance

calculated. These mean squares were used to determine the F ratio for each source being tested. Using a table of F values (45), the calculated F ratios were tested at the 0.10, 0.05 and 0.01 levels of significance.

The null hypothesis that there is no significant difference in the mean error of the measured cycle normal time due to the different methods is rejected at the 0.01 level of significance; it can not be rejected at the 0.05 level of significance. This means that, at the 0.10 level of significance, one method is more consistent than other; this is not true at the 0.05 level, of significance. Method C has less mean error than Method B, which has less mean error than Method A. This may be interpreted to mean that Method C tends to be more consistently correct than Method B and Method A, and Method B tends to be more consistently correct than Method A.

The null hypothesis that there is no significant difference in the mean error of the measured normal cycle time for different cycles is rejected at the 0.01 level of significance. This means that the mean error of the measured cycle normal time varied from cycle to cycle. This result, which was certainly to be expected, is due to a number of causes such as the differences in the length of cycle times and the possible effect of these differences upon the time study man's ability to properly rate the operators level of performance.

The null hypothesis that there is no significant difference in the mean error of the measured cycle normal time due to the order in which the films were observed by the time study men can not be rejected. The result is highly desirable since the purpose of rotating the presentation of the films was to determine the effect of this factor and to eliminate it as a source of variation in subsequent tests.

The null hypothesis that there is no significant difference in the mean error of the measured cycle normal time due to the time study men is rejected at the 0.01 level of significance. Since most people vary so widely in most abilities and attributes, it was expected that this source of variation would be significant.

The null hypothesis that the effect of the method on the mean error of the measured cycle normal time does not vary with the order in which the films were observed by the time study men is rejected at the 0.01 level of significance. This means that the relative consistency of the methods in determining the correct cycle normal time depended upon the order in which the films were observed by the time study men. Each man did not use each method on each film; therefore, the dependence of the consistency of the methods upon the order of films seem a natural result of experimental design which, although undesirable, was unavoidable.

The null hypothesis that the effect of the method upon the mean error of the measured normal cycle time does not vary with the time study man is rejected at the 0.01 level of significance. This means that a particular method is more consistent for one man than it is for another man. This result does not seem too unusual when consideration is given to the large mean square of the source of variation due to the time study men and the fact that most of the time study men seemed to be more familar with and had a preference for a particular method.

For further explanation of the significance of the methods time study men interaction, the method which each time study man preferred was compared to the method for which each time study man had the best performance; best performance was taken as being that method for which the time study man had the least total mean error of the measured cycle normal time. These comparisons are shown in Table 17 in the Appendix. The results of this comparison indicates that there is no significant correlation between the preference by the time study men and their performance on the various methods.

From both of the analyses of variance. standard deviations were calculated. The standard deviation of the mean error of the measured cycle normal time due to the cycle is 0.05650 minutes. The standard deviation of the mean error of measured cycle normal time for the time study men-cycle interaction is 0.04218 minutes. For the three-method analysis, the standard deviation of the mean error of the measured cycle normal time for the time study man is 0.07364 minutes. For the four-method analysis, the standard deviation of the mean error of the measured normal time for the time study men is 0.06767 minutes.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

This research has been concerned with a preliminary investigation of four methods of timing and rating work activity. These four methods are used in the practice of stop-watch time study. The primary objective of this research was an examination of the relative consistency of the four methods to correctly measure normal time values and of the relative consistency of three of these methods to measure correct cycle normal time values. The second objective was to determine some of the sources of variation within the methods.

As a result of the statistical analysis of the data of the experiment, the following results may be listed:

1. There was insufficient evidence to reject the null hypothesis that there is no significant difference in the conisstency of the four methods in measuring correct normal time.

2. A dependence of relative consistency of the methods upon the order of film presentation was indicated:

    a. Method A was more consistent for Order 1,

    b. Method B was more consistent for Order 4,

    c. Method C was more consistent for Order 3,

    d. Method D was more consistent for Order 4.

3. The standard deviation of the mean error of the measured normal time for the time study men was 0.06767 minutes.

4. Method C measured correct cycle normal time more consistently than either Method B or Method A. Method B measured correct cycle normal time more consistently than Method A. These differences were not significant at the 0.05 probability level, but were at the 0.10 level.

5. In the three-method analysis, a dependence of relative consistency of the methods upon the order of film presentation was indicated:

   a. Method A was more consistent for Order 1,

   b. Method B was more consistent for Order 2,

   c. Method C was more consistent for Order 3.

6. The relative consistency of the ability of the three methods to determine correct cycle normal time depended upon the time study man.

7. There was no significant correlation between the method preferred by a time study man and the method for which he had the best performance.

8. The standard deviation of the mean error of the measured cycle normal time for the cycle was 0.05650 minutes.

9. The standard deviation of the mean error of measured cycle normal time for the cycle-time study men interaction was 0.04218 minutes.

10. The standard deviation of the mean error of the measured cycle normal time for the time study man was 0.07364 minutes.

Any conclusions based upon the above results should be made in light of the limitations of this investigation. Only one operator performing one operation was studied. Furthermore, the operation was a manual one in which the level of performance was controlled by the operator. This last limitation would restrict any conclusions made to being applicable to manual, operator-controlled operations or work activities. The sample of time study men was assumed to be random. This would appear, however, to have less effect upon the validity of the results than the fact that each man did not use each method on each film. Motion pictures of the operation rather than the operation in its natural environment were studied. Research, presently being conducted at the Georgia Institute of Technology should provide an indication of the effect of this limitation upon the results of this study. The methods were used in only one sequence, the selection of which was subjective; however, it is felt that the effect of this source of error is negligible. The assumptions implied by the use of the procedure of analysis of variance may not be valid. It is believed, however, that deviations from these assumptions are not of such extent as to invalidate the results from the analysis of variance tests that were made. Perhaps the greatest limitation upon the results of this experiment was the method of determination of the correct rating factors. These determinations involved a pooled mean judgement by part of the sample of time study men, thereby introducing possible biases in the results of their errors. Naturally, this method of determining "correct" rating factors was both arbitrary and subjective.

In view of the above discussed limitations, the following general conclusions may be made:

1. The results of this investigation does not indicate any significant difference inthe consistency of the four methods in measuring normal time for manual, operator-controlled work activity.

2. Based upon the results of this experiment, selection and use of one of the four methods of timing and rating should depend to some extent upon the individual time study man.

The final selection of a particular method should take into consideration such additional factors as being able to detect minor methods deviations when timing elements, use of elemental time values, in the design of predetermined time systems, and use of element time values and cycle rating factors in the development of standard data systems.

In order to further validate the results and findings of this preliminary investigation of the four methods, it is recommended that further examination be made of the four methods. It is strongly suggested that in this further exploration the time study men make the observations in the actual industrial environment of the operation in order to avoid some of the disadvantages and difficulties of timing and rating silent motion pictures of an operation. It is also recommended that the sequence of use of the four methods be rotated so as to provide for the best possible sequence and to eliminate this factor as a source of possible error. It is highly recommended that a system or procedure for determining the "correct" rating factor be developed or used which will not involve the judgement of any of the observers. It should be realized, of course, that any such procedure or system will be subjective and arbitrary. This arbitrary base does not invalidate any measure of consistency, however, it does eliminate any conclusions concerning accuracy.

It is recommended that the scope of any further investigation be extended to include other types of work activity and other cycle lengths. In this way the results and findings of the experiment could have wider application.

APPENDIX

Element 1	When operator releases a finished shirt as she places it on a stack.
Element 2	When operator's right hand releases shirt-backing board at completion of insertion of it into the shirt collar.
Element 3	When operator's left hand releases the clothes pin at the completion of placing it on the shirt fold.
Element 4	When operator's left hand releases the clothes pin subsequent to the removal of it from the shirt fold.
Element 5	When operator's right hand first contacts the handle of the iron prior to the ironing of the shirt collar.

The starting point of an element is the ending point of the proceeding element.

Figure 1. Element Breakpoints of the Operation

1. (Given immediately before the first film was shown.)

You will now use the top sheet you have been given. You will use the method of timing the entire cycle and rating the entire cycle. There are 11 cycles. Start timing when you first see an image of the operation appear on the screen. A few seconds before the first image appears you will see a series of blue vertical marks. These are to allow you to be prepared to start timing. Shortly after the blue marks appear, the first image will appear.

2. (Given immediately after each film was shown.)

Take the top sheet off the pile, turn it over, and place it on the bottom of the pile.

3. (Given immediately before the second film was shown.)

You will now use the top sheet you have been given. You will use the method of timing each element and rating each cycle. There are 11 cycles. Start timing when you first see an image of the operation appear on the screen. A few seconds before the first image appears you will see a series of blue vertical marks. These are to allow you to be prepared to start timing. Shortly after the blue marks appear, the first image will appear.

4. Same as number 2.

5. (Given immediately before the third film was shown.)

You will now use the top sheet you have been given. You will use the method of timing each element and rating each element. There are 11 cycles. Start timing when you first see an image of the operation appear on the screen. A few seconds before the first image appears you will see a series of blue vertical marks. These are to allow you to be prepared to start timing. Shortly after the blue marks appear, the first image will appear.

6. Same as number 2.

7. (Given immediately before the fourth film was shown.)

You will now use the top sheet you have been given. You will use the method of timing each element and determining an over-all rating for each element for the 11 cycles. There will be 11 cycles. Start timing whan you first see an image of the operation appear on the screen. A few seconds before the first image appears, you will see a series of blue vertical marks. These are to allow you to be prepared to start timing. Shortly after the blue marks appear, the first image will appear.

8. Same as number 2.

9. (Given immediately after number 8.)

You will now hand all of the observation sheets, including the practice session one, to me.

Figure 2. Instructions Given During the Experiment

Table 9. Correct Time Values, in Thousandths of a Minute, for Each Element of Each Cycle
Film 1

Cycle Number Of	Element 1	2	3	4	5	Cycle Time
1	126	121	160	121	145	673
2	130	133	191	112	83	649
3	247*	154	190	117	109	817
4	127	179	180	150	97	733
5	148*#	166	198	144	117	773
6	137	155	161	121	144	718
7	142	161	158	122	128	711
8	125	174	158	103	179	739
9	125	164	150	130	119	688
10	243##	102	169	107	169	790
11	123	125	159	105	129	641

* Toss two defective shirts aside and wait -- 111
** Push stack of shirts aside -- 13
\# Toss one defective shirt aside -- 38
\## Toss one defective shirt aside -- 54

Table 10. Correct Time Values, in Thousandths of a Minute, for Each Element of Each Cycle
Film 2

Cycle Number Of	Element 1	2	3	4	5	Cycle Time
1	195*	107	143	88	114	647
2	121	120	188	94	95	609
3	120	115	171	91	75	572
4	116	80	199	114	74	563
5	116	99	151	96	91	553
6	122	112	157	100	126	617
7	148**	94	222	112	100	676
8	118	101	170	110	105	604
9	119	102	155	139	131	646
10	115	123	150	116	132	636
11	129	120	153	146	67	615

* Push stack of shirts aside -- 14
** Push stack of shirts aside -- 26

Table 11. Correct Time Values, in Thousandths of a Minute, for Each Element of Each Cycle
Film 3

Cycle Number Of	Element 1	2	3	4	5	Cycle Time
1	126	93	139	94	109	561
2	121	93	139	97	148	598
3	141	127	139	134	163	704
4	121	129	149	95	137	631
5	416*	122	184	101	114	937
6	155**	116	208	93	148	720
7	125	99	179	99	186	688
8	158#	139	158	101	114	670
9	179##	96	156	95	147	673
10	117	103	149	114	117	600
11	120	113	137	108	163	641

* Toss two defective shirts aside and wait -- 296
** Ironed back of shirt -- 62
\# Push stack of shirts aside -- 13
\## Push stack of shirts aside -- 35

Table 12. Correct Time Values, in Thousandths of a Minute, for Each Element of Each Cycle
Film 4

Cycle Number Of	1	2	3	4	5	Cycle Time
1	116	115	157	96	100	584
2	122	97	142	109	113	583
3	138	114	145	112	103	612
4	148	125	165	107	132	677
5	129*	103	141	167	132	672
6	129	98	167	119	134	647
7	136	100	159	105	101	601
8	260*	91	174	129	97	751
9	128	124	155	106	91	604
10	123	101	159	86	119	588
11	121	108	166	126	112	633

* Push stack of shirts aside -- 15
**Ironed back of shirt -- 88

Element 1 of Cycle 1

Normal Time = (Average Rating)(Frame Count Time)

For Group I

$$\text{Normal Time} = \frac{100 + 130 + 105}{3} \times 126 = 140.73$$

For Group IV

$$\text{Normal Time} = \frac{80 + 100 + 70}{3} \times 181 = 150.83$$

$$\text{Correct Normal Time} = \frac{\text{Normal Time - Group I} + \text{Normal Time - Group IV}}{2}$$

$$= \frac{140.73 + 150.83}{2} = 145.72$$

All time in thousandths of a minute

Figure 3. Sample Calculation for Determination of Correct Normal Time Values for Each Element of Each Cycle for All Films

Table 13. Correct Element Normal Time Value, in Thousandths of a Minute for Each Element of Each Cycle for All Films

Cycle Number Of	Element 1	2	3	4	5
1	145.72	106.70	148.12	95.50	125.38
2	137.94	116.22	188.99	106.67	125.02
3	163.88	132.70	172.32	130.67	119.60
4	136.19	117.21	186.37	122.08	112.31
5	137.67	128.92	184.96	109.95	113.89
6	147.23	129.52	193.03	108.92	149.67
7	202.08	110.11	219.12	118.97	149.43
8	131.53	133.64	176.43	111.47	124.18
9	137.65	113.10	174.67	122.15	147.21
10	136.31	130.63	171.68	127.06	132.55
11	142.75	131.92	167.44	136.05	123.51

Element 1, Cycle 1, Film 1

$$\text{Correct Rating} = \frac{\text{Correct Element Normal Time}}{\text{Frame Count Time}} \times 100$$

$$= \frac{145.72}{126} \times 100 = 115.65\%$$

Figure 4. Sample Calculation for Determination of Correct Rating Factor Values for Each Element of Each Cycle for Each Film

Table 14. Correct Element Rating Factor Values for Each Element of Each Cycle for Each Film

Film Number Of	Cycle Number Of	Element 1	2	3	4	5
	1	115.65	88.18	92.58	78.93	86.57
	2	106.11	87.38	98.95	95.24	150.63
	3	120.50	86.17	90.69	111.68	109.72
	4	107.24	65.48	103.54	81.39	115.78
	5	141.93	77.66	93.41	76.35	97.34
1	6	107.47	83.56	119.89	90.02	103.94
	7	142.33	68.39	138.62	97.52	116.74
	8	105.22	76.80	111.66	108.22	69.37
	9	110.12	68.96	116.45	93.95	123.71
	10	72.12	128.07	101.59	118.75	78.43
	11	116.06	105.54	105.54	129.57	95.74
	1	80.51	99.72	103.58	108.52	109.98
	2	114.00	96.85	100.53	113.48	131.60
	3	136.57	115.39	100.77	143.59	159.47
	4	117.41	146.51	104.12	107.09	151.77
	5	118.68	130.22	122.49	114.53	105.15
2	6	120.68	115.64	122.95	108.92	118.79
	7	165.64	117.14	98.70	106.22	149.43
	8	111.47	132.32	103.78	101.34	118.27
	9	115.67	110.88	112.70	87.87	112.37
	10	118.53	106.20	114.45	109.53	100.42
	11	110.66	109.93	109.44	93.18	184.34

Table 14. Correct Element Rating Factor Values for Each Element of Each Cycle for Each Film

(Continued)

Film Number Of	Cycle Number Of	Element 1	2	3	4	5
	1	115.65	114.73	106.56	101.60	115.03
	2	114.00	124.97	135.96	109.97	84.47
	3	116.23	104.49	123.97	97.51	73.37
	4	112.55	90.86	125.08	128.51	81.98
	5	114.73	105.67	100.52	108.86	99.90
3	6	103.68	111.66	92.80	114.65	101.13
	7	161.66	111.22	122.41	120.17	80.34
	8	106.93	96.14	111.66	110.37	108.93
	9	117.64	117.81	111.97	128.57	100.14
	10	116.50	126.83	115.22	111.46	113.29
	11	118.96	116.74	122.22	125.97	75.77
	1	125.62	92.78	94.34	99.48	125.38
	2	113.07	119.81	133.09	97.86	110.64
	3	118.28	116.40	118.84	116.67	116.12
	4	92.22	93.77	112.95	114.09	85.08
	5	120.76	125.17	131.18	65.84	86.28
4	6	114.13	132.16	115.59	91.53	111.69
	7	148.59	110.11	137.81	113.30	147.95
	8	76.47	146.86	101.40	86.41	128.02
	9	107.54	91.21	112.69	115.23	161.77
	10	110.82	129.34	107.97	147.74	111.39
	11	117.98	122.15	100.87	107.98	110.28

Element 1, Film 1

Cycle Number Of	Correct Element Normal Time	Element Frame Count
1	145.72	126
2	137.94	130
3	163.88	136
4	136.19	127
5	137.67	97
6	147.23	137
7	202.28	142
8	131.53	125
9	137.65	125
10	136.31	189
11	142.75	123
Totals	1618.95	1457

$$\text{Average Correct Normal Time} = \frac{\sum_{1}^{11} \text{Correct Element Normal Time}}{\text{Number of Cycles}}$$

$$= \frac{1618.95}{11} = 147.18$$

$$\text{Average Frame Count Time} = \frac{\sum_{1}^{11} \text{Element Frame Count}}{\text{Number of Cycles}}$$

$$= \frac{1457}{11} = 132.45$$

$$\text{Correct Element Rating Value} = \frac{\text{Average Correct Normal Time}}{\text{Average Frame Count Time}} \times 100$$

$$= \frac{147.18}{132.95} \times 100 = 111.12\%$$

Figure 5. Sample Calculation for Determination of Correct "Over-All" Rating Factor Values for Each Element for Each Film

Table 15. Correct "Over-All" Rating Factor Values for Each Element of Each Film

Film Number Of	Element 1	2	3	4	5
1	111.12	82.66	105.82	96.81	100.26
2	117.41	115.14	107.84	106.92	128.17
3	117.91	109.81	114.17	113.62	92.02
4	111.65	113.60	115.03	100.43	109.95

Cycle 1

$$\text{Correct Rating Value} = \frac{\text{Sum of Correct Element Normal Time}}{\text{Sum of Element Frame Count Time}} \times 100$$

$$= \frac{145.72 + 106.70 + 148.12 + 95.50 + 125.38}{126 + 121 + 160 + 121 + 145}$$

$$= 92.34\%$$

Figure 6. Sample Calculation for Determination of Correct Rating Factor Values for Each Cycle of Each Film

Table 16. Correct Cycle Rating Factor Values for Each Cycle of Each Film

Cycle Number Of	Film			
	1	2	3	4
1	92.34	98.17	110.77	106.41
2	103.98	109.20	124.05	115.75
3	101.87	125.73	102.15	117.51
4	91.97	119.74	113.30	99.58
5	93.54	122.13	105.37	102.80
6	101.44	118.05	102.73	112.58
7	112.48	123.03	117.24	133.06
8	91.64	112.13	106.65	102.15
9	100.98	107.55	113.71	115.03
10	94.87	109.78	116.37	118.75
11	109.46	114.09	109.46	110.85

Group I

Cycle Number Of	Correct Time	Correct Rating	Correct Cycle Normal Time
1	673	92.34	621.45
2	649	103.93	674.48
3	706	101.87	719.20
4	733	91.97	674.14
5	722	93.54	675.36
6	718	101.44	728.34
7	711	112.48	799.33
8	739	91.64	666.31
9	688	100.98	694.74
10	736	94.87	698.24
11	641	109.46	701.39
		Total	7652.98

$$\text{Correct Normal Time} = \frac{\text{Sum of Correct Cycle Normal Time Values}}{\text{Number of Cycles}} \times \frac{1}{1000}$$

$$= \frac{7652.98}{11} \times \frac{1}{1000} = 0.69570 \text{ minutes}$$

Figure 7. Sample Calculation for Determination of Correct Normal Time Values for Method A

Group I

Cycle Number Of	Cycle Time	Correct Rating	Correct Cycle Normal Time
1	635	98.17	623.38
2	609	109.20	665.03
3	572	125.73	719.18
4	563	119.74	674.14
5	553	122.13	675.38
6	617	118.05	728.84
7	650	123.03	799.70
8	604	112.13	677.27
9	646	107.55	694.48
10	636	109.78	698.20
11	615	114.09	701.65
		Total	7657.22

$$\text{Correct Normal Time} = \frac{\text{Sum of Correct Cycle Normal Time Values}}{\text{Number of Cycles}} \times \frac{1}{1000}$$

$$= \frac{7657.22}{11} \times \frac{1}{1000} = 0.69611 \text{ minutes}$$

Figure 8. Sample Calculation for Determination of Correct Normal Time Values for Method B

For All Groups

Cycle Number Of	Correct Normal Time for Element 1	2	3	4	5	Total Correct Element Normal Time
1	145.72	106.70	148.12	95.50	125.38	621.42
2	137.94	116.22	188.99	106.67	125.00	536.90
3	163.88	132.70	172.32	130.67	119.60	719.17
4	136.19	117.21	186.37	122.08	112.31	674.16
5	137.67	128.92	184.96	109.95	113.89	537.37
6	147.23	129.52	193.03	108.92	149.67	728.37
7	202.08	110.11	219.12	118.97	149.43	799.71
8	131.53	133.64	176.43	111.47	124.18	677.25
9	137.65	113.10	174.67	122.14	147.21	604.77
10	136.31	130.63	171.68	127.06	132.55	698.23
11	142.75	131.92	167.44	136.05	123.51	700.67
					Total	7388.37

$$\text{Correct Normal Time} = \frac{7388.37}{11} \times \frac{1}{1000} = 0.67167 \text{ minutes}$$

$$\text{Correct Normal Time} = \frac{\text{Sum of Total Correct Element Normal Time Values}}{\text{Number of Cycles}} \times \frac{1}{1000}$$

$$= \frac{7388.37}{11} \times \frac{1}{1000} = 0.67167 \text{ minutes}$$

Figure 9. Sample Calculation for Determination of Correct Normal Time Values for Method C

Group II

Cycle Number Of	Correct Time for Element 1	2	3	4	5
1	126	121	160	181	145
2	130	133	191	112	83
3	136	154	190	117	109
4	127	179	180	150	97
5	97	166	198	144	117
6	137	155	161	121	144
7	142	161	158	122	128
8	125	174	158	103	179
9	125	164	150	130	119
10	189	102	169	107	169
11	123	125	159	105	129
Correct Rating Factor	111.12	82.66	105.82	96.81	100.26

$$\text{Correct Normal Time} = 10^{-5} \sum_{1}^{e} \frac{\sum_{1}^{c} \text{Correct Element Time}}{\text{Number of Cycles}} \times \text{Correct Rating Factor}$$

$$= 10^{-5} \times 69687 = 0.69687 \text{ minutes},$$

where e is the number of elements and c is the number of cycles.

Figure 10. Sample Calculation for Determination of Correct Normal Time Values for Method D

For Man 1

Measured Cycle Time in Minutes	Measured Cycle Rating	Measured Cycle Normal Time in Minutes
.590	90	.5310
.550	95	.5225
.589	80	.4712
.640	88	.5632
.659	80	.5272
.610	90	.5490
.610	90	.5490
.630	90	.5670
.600	95	.4800
.626	100	.6260
.550	110	.6050
	Total	5.9911

$$\text{Normal Time} = \frac{\text{Sum of Measured Cycle Normal Time Values}}{\text{Number of Cycles}} \times 100$$

$$= \frac{5.9911}{11} = 0.54460 \text{ minutes.}$$

Note: Where applicable frame count time for foreign elements have been subtracted from man's reading

Figure 11. Sample Calculation for Determination of Measured Normal Time Values for Method A

Man 1

Cycle Number Of	Measured Cycle Time	Measured Cycle Rating	Measured Cycle Normal Time
1	.506	95	.4807
2	.440	95	.4180
3	.440	110	.4840
4	.430	100	.4300
5	.440	90	.3960
6	.490	85	.4165
7	.544	85	.4624
8	.470	100	.4700
9	.530	99	.5247
10	.500	90	.4500
11	.540	85	.4590
		Total	4.9913

$$\text{Measured Cycle Normal Time} = \frac{\text{Measured Cycle Time X Measured Cycle Rating}}{100}$$

$$\text{Measured Normal Time} = \frac{\text{Sum of Cycle Normal Time Value}}{\text{Number of Cycles}}$$

$$= \frac{4.9913}{11} = 0.45375 \text{ minutes.}$$

Note: Where applicable, frame count time for foreign elements have been subtracted from man's watch reading.

Figure 12. Sample Calculation for Determination of Measured Normal Time Values for Method B

Man 1

Cycle Number Of		Element 1	Element 2	Element 3	Element 4	Element 5		Cycle Normal Time
1	=	.100 X 100	.080 X 99	.100 X 90	.080 X 110	.080 X 95	=	.43320
2	=	.120 X 99	.060 X 105	.110 X 92	.080 X 110	.120 X 90	=	.47900
3	=	.180 X 95	.100 X 90	.120 X 94	.100 X 99	.130 X 85	=	.53580
4	=	.120 X 90	.100 X 100	.120 X 95	.100 X 90	.100 X 99	=	.51190
5	=	.084 X 100	.100 X 100	.150 X 90	.090 X 100	.100 X 95	=	.50400
6	=	.127 X 95	.090 X 100	.190 X 85	.080 X 105	.120 X 90	=	.56415
7	=	.110 X 105	.080 X 110	.150 X 90	.090 X 102	.150 X 90	=	.56530
8	=	.105 X 90	.130 X 99	.130 X 100	.090 X 100	.080 X 110	=	.53120
9	=	.198 X 100	.090 X 100	.130 X 99	.080 X 105	.120 X 98	=	.60870
10	=	.120 X 105	.080 X 105	.120 X 98	.100 X 100	.100 X 105	=	.53260
11	=	.130 X 100	.080 X 100	.120 X 98	.100 X 100	.140 X 98	=	.56480
						Total		5.83165

$$\text{Measured Cycle Normal Time} = \frac{\text{Sum of the Measured Element Times X Element Ratings}}{100}$$

$$\text{Measured Normal Time} = \frac{\text{Sum of the Cycle Normal Times}}{\text{Number of Cycles}} = \frac{5.831365}{11} = 0.53015 \text{ minutes}$$

Note: Where applicable, frame count time for foreign elements have been subtracted from man's reading.

Figure 13. Sample Calculation for Determination of Measured Normal Time Values for Method C

Man 1

Cycle Number Of	Element 1	2	3	4	5
1	.100	.080	.150	.070	.070
2	.120	.080	.110	.100	.090
3	.130	.090	.120	.090	.080
4	.150	.080	.130	.090	.100
5	.105	.080	.110	.140	.100
6	.120	.080	.130	.100	.110
7	.120	.080	.130	.090	.090
8	.132	.070	.140	.100	.070
9	.120	.090	.120	.100	.070
10	.120	.070	.130	.060	.100
11	.120	.100	.120	.100	.100
Totals	1.337	.900	1.390	1.040	.980
Rating Factor	99	105	100	95	100

$$\text{Measured Normal Time} = \frac{1}{100} \sum_{1}^{e} \frac{\sum_{1}^{c} \text{Element Time}}{\text{Number of Cycles}} \text{ X Element Rating Factor}$$

$= \frac{51145}{100} = 0.51145$ minutes, where e is the number of elements and

c is the number of cycles.

Figure 14. Sample Calculation for Determination of Measured Normal Time Values for Method D.

Analysis of Variance Table

Source	Model	Subscript	Symbol	Number of Levels
Method	I	j	M	J = 4
Order	I	k	O	K = 4
Men	II	l	t	L = 3

Model I denotes a fixed effect, and Model II denotes a random variate. Since the time study men variable is nested in the order variable, the number of levels for time study men is 3 instead of 12.

$$x_{j(k)l} = \mu + M_j + O_k + t_{(k)l} + Mt_{j(k)l} + MO_{jk}$$

Since t is nested in O, k is a "dead" or "unessential" subscript.

From the model equation, the expected values of the mean squares is determined. These are given below.

Source	Expected Value of Mean Squares
M	$\sigma^2_{Mt} + KL\,\sigma^2_M$
O	$J\,\sigma^2_{t(O)} + JL\,\sigma^2_O$
t	$J\,\sigma^2_{t(O)}$
MO	$\sigma^2_{Mt} + L\,\sigma^2_{MO}$
Mt	σ^2_{Mt}

Figure 15. Determination of Expected Values of Mean Squares - Four Method Analysis

Analysis of Variance Table

Source	Model	Subscript	Symbol	Number of Levels
Cycles	II	i	c	I = 11
Method	I	j	M	J = 3
Order	I	k	O	K = 4
Men	II	l	t	L = 3

Model I denotes a fixed effect, and Model II denotes a random variate.

$$x_{ijkl} = \mu + c_{i(jk)} + M_j + O_k + t_{(k)l} + MO_{jk} + ct_{i(j)(k)l} + Mt_{j(k)l}$$

Since t is nested in O, k is a "dead" or "unessential" subscript. c is nested in M; therefore, j is a "dead" or unessential" subscript. Also, c is nested in O.

The expected values of the mean squares are shown below.

Source	Expected Value Of Mean Squares
c	$\sigma^2_{ct} + L\,\sigma^2_{c}$
M	$\sigma^2_{ct} + I\,\sigma^2_{Mt} + IKL\,\sigma^2_{M}$
O	$\sigma^2_{ct} + IJ\,\sigma^2_{t} + IJL\,\sigma^2_{O}$
t	$\sigma^2_{ct} + I\,\sigma^2_{Mt} + IJ\,\sigma^2_{t}$
MO	$\sigma^2_{ct} + L\,\sigma^2_{c} + IL\,\sigma^2_{MO}$
Mt	$\sigma^2_{ct} + I\ {}^2_{Mt}$
ct	σ^2_{ct}

Figure 16. Determination of Expected Values of Mean Squares - Three Method Analysis

Table 17. Time Study Mens' Preference of and Performance on Methods A, B, and C

Time Study Men Number Of	Method Time Study Men Preferred	Method of Best Performance
1	B	C
2	A	B
3	B	A
4	B	C
5	B	C
6	C	C
7	B	C
8	B	C
9	C	B
10	B	B
11	A	B
12	A	B

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